

The Nitrate Contamination of Private Well Water in Iowa

ABSTRACT

The State-Wide Rural Well-Water Survey was conducted between April 1988 and June 1989. About 18% of Iowa's private, rural drinking-water wells contain nitrate above the recommended health advisory level (levels of $\text{NO}_3\text{-N}$ greater than 10 mg/L); 37% of the wells have levels greater than 3 mg/L, typically considered indicative of anthropogenic pollution. Thirty-five percent of wells less than 15 m deep exceed the health advisory level, and the mean concentration of nitrate-nitrogen for these wells exceeds 10 mg/L. Depth of well is the best predictor of well-water contamination. Individually, $\text{NO}_3\text{-N}$ levels of more than 10 mg/L occurred alone in about 4% of the private wells statewide; pesticides were present alone in about 5%. Total coliform positives occurred alone at 27% of the sites. In a cumulative sense, these three contaminants were detected in nearly 55% of rural private water supplies. (*Am J Public Health*. 1993;83:270-272)

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Introduction

The State-Wide Rural Well-Water Survey addresses two questions: What proportion of private rural wells in Iowa are affected by various environmental contaminants? What proportion of rural Iowa residents are using well water containing these environmental contaminants? Results of the survey provide, for the first time, statistically valid statewide estimates of the extent of groundwater contamination in rural private wells. Details of the design and operation of the survey are reported elsewhere.¹

The drinking water standard for nitrate was set primarily to prevent infant cyanosis, or methemoglobinemia (blue-baby syndrome), a temporary blood disorder that reduces the ability of an infant's bloodstream to carry oxygen through the body.² Acute and fatal incidents of methemoglobinemia have been reported in the past in Iowa,³ and recently in South Dakota.⁴

There are also growing concerns related to long-term and chronic exposure to nitrate alone and in combination with other contaminants. Subclinical methemoglobinemia, which still removes oxygen from the system of a developing infant, could have subtle, long-term developmental or neurological effects.⁵ Some evidence exists from epidemiological studies that high nitrate ingestion is involved in the etiology of human cancer.^{6,7} High nitrate levels in groundwater have been associated with increased rates of non-Hodgkin's lymphoma in a Nebraska study.⁸ An Australian epidemiological study associated high nitrate in drinking water with increased birth defects,⁹ while a follow-up study with pregnant rats did not identify a teratogenic agent in the same water.¹⁰ A Canadian case-control study¹¹ suggested a moderate, but not significant, increase in risk for central nervous system birth defects. While these and other studies have been suggestive, results have been equivocal and inconsistent among different studies. The US Environmental Protection Agency has indicated that there is insufficient information currently available to determine whether or not nitrate causes cancer in humans. The current drinking

water standard and health advisory level of 10 mg/L $\text{NO}_3\text{-N}$ (equivalent to 10 parts per million $\text{NO}_3\text{-N}$ or 45 parts per million NO_3) is based only on the noncancer health effects related to infantile methemoglobinemia.

Much of adults' nitrate intake may come from their diet, particularly green vegetables. With children, water intake is proportionately much more important, and often the dominant input.

An important public health consideration is that private, rural well-water supplies used by most farm families and rural populations are not regulated by any public health or environmental agency. Public water supplies are routinely monitored for nitrate levels, and whenever these supplies exceed the nitrate standard, public notification via broadcast and print media is required. However, similar water testing programs and warnings are not typically provided for rural populations using private wells.

Methods

The State-Wide Rural Well-Water Survey was conducted between April 1988 and June 1989 to provide a statistically valid assessment of the proportion of private, rural wells and rural Iowa residents affected by various environmental contaminants. The survey involved a systematic sample stratified by rural population density. The results are likely representative of conditions in other rural areas with intensive agricultural production.

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This paper was submitted to the *Journal* July 10, 1991, and accepted with revisions September 23, 1992.

A sampling grid was constructed from the intersection of every 5 minutes of latitude and longitude within the state. This grid provided a systematic framework across the state, unaffected by any external bias. The sample scheme was then stratified by the rural population density of each county. The drinking-water well closest to each chosen intersection was selected as the target for sampling. In this fashion, 686 samples were collected, some from each county in the state.

Results

Low concentrations of nitrate occur naturally in some uncontaminated groundwater. Concentrations over 3 mg/L nitrate-nitrogen are usually considered indicative of anthropogenic pollution.¹² The natural background concentration in groundwater aquifers in Iowa is typically less than 2 mg/L $\text{NO}_3\text{-N}$, and is often less than 1 mg/L $\text{NO}_3\text{-N}$.¹³⁻¹⁵ Higher concentrations in Iowa indicate a degree of pollution related to agricultural practices, fertilizer use, manure, septic tank wastes, sewage sludge, or other sources.

As summarized in Tables 1 and 2, the survey results clearly indicate widespread contamination of groundwater with nitrate. Approximately 18.3% of Iowa's private, rural drinking-water wells contain nitrate at concentrations exceeding the recommended health advisory level. Thirty-five percent of wells less than 15 m deep exceed 10 mg/L $\text{NO}_3\text{-N}$; in fact, the mean concentration for these wells is over 10 mg/L. As shown in Figure 1, approximately 30% of all wells in southern and western Iowa exceed the health advisory level, reaching a maximum of 38% in northwestern Iowa. Regional variations in nitrate contamination are significant.

The survey was designed to allow a population exposure estimate to be made. Based on 1980 census data, about 130 000 rural Iowa residents (or about 17.9% of the rural population) are consuming drinking water with unacceptably high concentrations of nitrate. The population percentage is slightly less than the percentage of contaminated wells cited earlier because some of the participants used rural water district water supplies, and not their wells, for their primary drinking water.

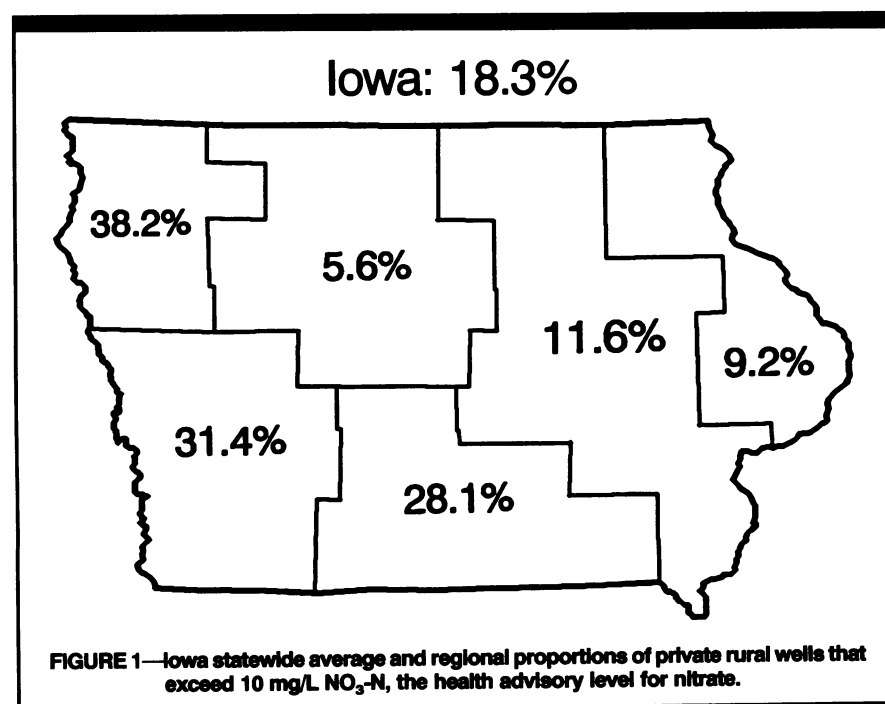
Individually, $\text{NO}_3\text{-N}$ levels greater than 10 mg/L occurred alone in about 4% of the water supplies statewide; pesticides were present alone in about 5%. Total coliform positives occurred alone at 27% of the sites, representing over 60% of the total coliform positives. In a cumulative

TABLE 1—Summary of Nitrate-Nitrogen Concentration Data, Statewide, by Well Depth and by Hydrogeologic Region

	$\text{NO}_3\text{-N}$ >10 mg/L (Health Advisory Level), %	95% CI	Concentration of $\text{NO}_3\text{-N}$, mg/L				Wells in Class, %
			Mean	SD	Median	Range	
Statewide	18.3	15.4, 21.2	6.2	12.2	0.55	≤0.1–100	100.0
Wells < 15 m	35.1	27.4, 42.8	11.2	15.7	6.0	<0.1–95	27.9
Wells > 15 m	12.8	9.6, 16.1	4.3	10.7	<0.1	<0.1–100	72.1
Hydrogeologic region							
Northeastern	9.2	3.0, 15.4	3.5	5.5	1.3	<0.1–37	13.0
Eastern	11.6	7.3, 15.9	2.6	5.3	<0.1	<0.1–50	32.3
South-central	28.1	20.2, 35.9	9.5	14.0	2.1	<0.1–87	17.5
Southwestern	31.4	22.0, 40.9	10.2	19.4	5.2	<0.1–100	14.2
Northwestern	38.2	46.8, 73.2	14.1	19.7	5.2	<0.1–95	7.9
North-central	5.6	1.2, 9.9	2.4	9.0	<0.1	<0.1–79	15.1

TABLE 2—Percentage of Iowa Wells with Water Analyses in Different Ranges of Nitrate Concentration

	$\text{NO}_3\text{-N}$ Concentration, mg/L					$\text{NO}_3\text{-N}$ >3.0 mg/L	$\text{NO}_3\text{-N}$ >10.0 mg/L
	<0.1	0.1–3.0	3.1–10.0	10.1–20.0	>20.1		
Statewide	42.2	20.4	19.1	10.1	8.2	37.4	18.3
Wells ≤ 15 m	11.7	21.3	31.9	19.5	15.6	67.0	35.1
Wells > 15 m	54.1	20.0	13.0	7.9	4.9	25.8	12.8
Hydrogeologic region							
Northeastern	45.1	20.9	24.9	8.3	0.9	34.0	9.2
Eastern	58.2	15.0	15.0	7.0	4.6	26.6	11.6
South-central	20.0	33.3	18.3	14.1	14.0	46.4	28.1
Southwestern	21.4	21.4	25.5	17.2	14.2	56.9	31.4
Northwestern	20.0	12.7	29.1	18.2	20.0	67.3	38.2
North-central	68.6	17.1	8.6	2.8	2.8	14.2	5.6



sense, these three contaminants, individually or in combination, were detected in

nearly 55% of rural private water supplies. If fecal coliform occurrences are used in

lieu of total coliforms, this figure decreases to about 30% of well-water supplies. No sites with fecal coliforms had pesticide detections, and only about 2.5% were positive for both fecal coliforms and levels of $\text{NO}_3\text{-N}$ greater than 10 mg/L. Detailed discussions of other water quality tests conducted for the survey are provided elsewhere.¹⁶

Discussion

We calculated the mean concentrations for nitrate, presented in Table 1, using all samples (i.e., those samples providing results lower than the detection limits were set equal to zero). This produces a considerably lower value than a mean calculated from the quantifiable detections. It also results in a very large standard deviation, with values actually greater than the mean.

The University Hygienic Laboratory, Iowa's state environmental laboratory, analyzes about 10 000 to 12 000 samples per year for nitrate; most of these samples are taken from private drinking-water wells. Throughout the 1980s, results from these analyses consistently indicated that more than 15% of all samples, and 15% to 24% of well samples, exceeded the recommended health advisory level for nitrate.

To reiterate, the concern with nitrate contamination in Iowa, and more generally for many agricultural regions, is not that the problem was unknown until recent years or that high concentrations were not present locally. The problem is manifested in the regional increases in concentrations and the extension of greater concentrations to depth in groundwater systems. Nitrate has become a nearly ubiquitous contaminant in the shallow groundwater system.

Considerable monitoring has been undertaken in other states and agricultural regions of the world.¹⁷⁻²⁰ In Nebraska, a regional study of 451 farm wells found that 8% had levels of $\text{NO}_3\text{-N}$ greater than 10 mg/L; 4% showed pesticide detections. A Kansas statewide survey of 104 wells found that 28% had $\text{NO}_3\text{-N}$ levels greater than 10 mg/L, and 9% showed pesticide detections. These findings are comparable to the present survey data.

Conclusion

Health care professionals working in rural areas should recognize that private

drinking-water wells frequently contain one or more environmental contaminants. Well-water contamination is more common and more serious today than it was a decade ago. Shallow wells that were constructed several years ago may have tested safe initially but may now contain greater concentrations or even unsafe levels of nitrate or other environmental contaminants.

Normal prenatal care for rural patients should include a recommendation to have private wells tested for nitrate. If excess nitrate concentration is determined, the well water should not be used in preparing infant formula or otherwise consumed by infants, particularly those less than 6 months of age. Boiling of water contaminated with nitrate is not effective and, in fact, actually increases the concentration of nitrate because of evaporation.

In Iowa, agricultural application of nitrogen (commercial fertilizer and livestock manure disposal) is the major source of environmental nitrate contamination.²¹ Additional efforts are needed to substantiate the relationship between reduced fertilizer usage and improved groundwater quality. Finally, groundwater protection strategies, such as sustainable agriculture practices, should be considered as part of a national policy to prevent groundwater contamination. □

References

- Hallberg GR, Kross BC, Libra RD, et al. *The Iowa State-wide Rural Well-Water Survey: Design Report: A Systematic Sample of Domestic Drinking Water Quality*. Iowa City, Iowa: Iowa Department of Natural Resources; 1990. Technical Information Series 17.
- Johnson CJ, Kross BC. Continuing importance of nitrate contamination of groundwater and wells in rural areas. *Am J Ind Med*. 1990;18:449-456.
- Comly HH. Cyanosis in infants caused by nitrates in well water. *JAMA*. 1945;129:112-117.
- Johnson CJ, Bonrud PA, Dosch TL, et al. Fatal outcome of methemoglobinemia in an infant. *JAMA*. 1987;257:2796-2797.
- Nitrate: rerun of an old horror. *Health Environ Digest*. 1988;1(12):1-3.
- Fraser P, Chilvers C, Beral V, Hill MJ. Nitrate and human cancer: a review of the evidence. *Int J Epidemiol*. 1980;9:3-9.
- Forman D, Al-Dabbagh S, Doll R. Nitrates, nitrites and gastric cancer in Great Britain. *Nature*. 1985;313:620-625.
- Weisenburger DD. Environmental epidemiology of Non-Hodgkin's lymphoma in Eastern Nebraska. *Am J Ind Med*. 1990;18:303-306.
- Dorsch MM, Scragg RK, McMichael AJ, Baghurst PA, Dyer KF. Congenital malformations and maternal drinking water supply in rural South Australia: a case control study. *Am J Epidemiol*. 1984;119:473-486.
- Dreosti IE, McMichael AJ, Bridle TM. Mount Gambier drinking water and birth defects: a laboratory study in rats after earlier epidemiological findings. *Med J Aust*. 1984;141:409-411.
- Arbuckle TE, Sherman GJ, Corey PN, Walters D, Lo B. Water nitrates and CNS birth defects: a population-based case-control study. *Arch Environ Health*. 1988;43:162-167.
- Madison RJ, Brunett JO. Overview of the occurrence of nitrate in ground water of the United States. In: *National Water Summary 1984*. Reston, Va: US Geological Survey; 1985:93-105. Water-Supply Paper 2275.
- Hallberg GR, Libra RD, Long KR, Splinter RC. Pesticides, groundwater, and rural drinking water quality in Iowa. In: *Pesticides and Groundwater: A Health Concern for the Midwest*. Navarre, Minn: The Freshwater Foundation and the US Environmental Protection Agency; 1987:83-104.
- Libra RD, Hallberg GR, Rasmeyer GR, Hoyer BE. Groundwater quality and hydrogeology of Devonian-Carboniferous aquifers in Floyd and Mitchell counties, Iowa. Iowa City, Iowa: Iowa Geological Survey; 1984.
- Hallberg GR, Libra RD, Quade DJ, Littke J, Nations B. *Groundwater Monitoring in the Big Spring Basin, 1984-1987: A Summary Review*. Iowa City, Iowa: Iowa Department of Natural Resources; 1989. Technical Information Series 16.
- Kross BC, Hallberg GR, Bruner DR, et al. *The Iowa State-wide Rural Well-Water Survey: Water-Quality Data: Initial Analyses*. Iowa City, Iowa: Iowa Department of Natural Resources; 1990. Technical Information Series 19.
- Hallberg GR. Nitrate in groundwater in the United States. In: Follett RF, ed. *Nitrogen Management and Groundwater Protection*. Amsterdam, The Netherlands: Elsevier; 1989:35-74.
- Domestic Well Water Sampling in Central Nebraska: Laboratory Findings and Their Implications*. Lincoln, Neb: Nebraska Department of Health; 1985.
- Koelliker JK, Steichen JM, Yearout RD, Heiman AT, Grosh DL. *Identification of Factors Affecting Farmstead Well Water Quality in Kansas*. Manhattan, Kan: Kansas Water Resources Research Institute, Kansas State University; 1987. Report G1226-02.
- LeMasters G, Doyle DJ. *Grade A Dairy Farm Well Water Quality Survey*. Madison, Wis: Wisconsin Department of Agriculture, Trade and Consumer Protection and Wisconsin Agricultural Statistics Service; 1989.
- Hoyer BE, Combs JE, Kelley RD, Cousins-Leatherman C, Seby JH. *Iowa Groundwater Protection Strategy 1987*. Des Moines, Iowa: Environmental Protection Commission, Iowa Department of Natural Resources; 1987.